

# Architectural Models of Adaptive Hypermedia Based on the Use of Ontologies

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The domain of traditional hypermedia is revolutionized by the arrival of the concept of adaptation. Currently, the domain of AHS (adaptive hypermedia systems) is constantly growing. A major goal of current research is to provide a personalized educational experience that meets the needs specific to each learner (knowledge level, goals, motivation, etc.). In this article, we have studied the possibility of implementing traditional features of adaptive hypermedia in an open environment, and discussed the standards for describing learning objects and architectural models based on the use of ontologies as a prerequisite for such an adaptation.

**Keywords:** e-learning, learner modeling, adaptive educational hypermedia, ontologies, RDF (description framework), IMS LIP (information model specification learner information package)

## Introduction

E-learning is a very dynamic domain, constantly growing, which refers to educational contents or learning experiences delivered or made through digital technologies. The development of this domain has a direct impact on teaching quality and reducing costs. E-learning today is dominated by LMS (learning management systems), such as blackboard, Moodle, ATutor or Claroline, which are integrated systems that provide support for a wide area of activities in the e-learning process. Thus, teachers can use the LMS for course creation and test suites, communicate with students, monitor and evaluate their work. Students can learn, communicate and collaborate through LMS.

The problem is that LMS does not offer personalized services, presenting the same educational resources to different learners, regardless of different levels of knowledge, interest, motivation and objectives. As Morrison, Ross, and Kemp (2001) stated: “Just as people differ in many respects, so do ways in which they learn differ”. Some of these differences are evident in the types of experiences that each person needs to learn. It is, therefore, essential to start the process of planning, attention to the characteristics, capabilities and experiences of learners—as a group and as individuals. AEHS (adaptive educational hypermedia systems) try to provide an alternative approach to non-individualized, providing various services and tailored to the learner profile. The purpose of this adaptation is to maximize the subjective satisfaction of the learner, the learning speed (efficiency) and assessment results (effectiveness).

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There are two basic questions in AEHS:

(1) What can we adapt to? The answer includes several learner characteristics, such as knowledge, goals, tasks or interests, background and experience, learning style, context and environment;

(2) What can be adapted? The answer includes the presentation (adapting the actual content, the presentation of that content, or the media used) as well as the navigation (adapting the link anchors that are shown, the link destinations, and the overviews for orientation support).

In addition, AHS (adaptive hypermedia systems) for e-learning represent a continuously growing research domain, involving knowledge from several fields (adaptive systems, adaptive hypermedia, learning management systems, user modeling, educational psychology and instructional science).

Adaptation can take three forms (Edmonds, 1981):

(1) Adapted systems: in which adaptation is hard-wired by the application designer; in this case, the system is customized to a particular user profile, which is defined beforehand, at design time;

(2) Adaptable systems: in which adaptation is explicitly required by the user. More precisely, the user can specify her/his own preferences, by manually creating her/his profile; thus, the system is dealing with a fixed profile, which can only be modified by the users' intervention;

(3) Adaptive systems: in which adaptation initiative belongs to the system itself, based on continuous observation of the users' preferences and needs. The users' profile is no longer static, it is dynamically updated by the system, after tracking and analyzing the users' behaviors.

### **Adaptivity in E-learning**

A conceptual definition of adaptivity in e-learning refers to the creation of educational experiences that adjust to various conditions (personal characteristics, pedagogical approach, users' interactions and learning outcome) during a certain amount of time, in order to improve performance indicators (e-learning efficiency: results, time, costs and users' satisfaction). The functional definition refers, first of all, to the main characteristics provided by the system. An adaptive system must be capable of managing learning paths adapted to each user, monitoring users' activities, interpreting them using specific models, inferring users' needs and preferences and exploiting users' and domain knowledge to dynamically facilitate the learning process (Boticario, Santos, & van Rosmalen, 2005).

We can identify three major development paradigms in artificial intelligence in education:

(1) Intelligent computer-assisted instruction, using classic mainframes and mini-computers as platforms. The main goal of these systems is the transfer of knowledge to the students, therefore, the learning materials consisted mainly of presentations and also some exercises and problems. Correspondingly, the most popular technologies were curriculum sequencing and intelligent solution analysis (Koffman & Perry, 1976);

(2) Intelligent tutoring systems, using personal computers as the support platform. The main goal shifted from educational material presentation to supporting the students in solving problems and procedural knowledge formation. Consequently, the core technology became interactive problem-solving support;

(3) Web-based educational systems, having the WWW (World Wide Web) as support platform. The goals of these systems became more complex and diverse, including, at the same time, content delivery, problem-solving support and collaborative work support. Consequently, multiple technologies were employed, ranging from adaptive curriculum sequencing, adaptive hypermedia, adaptive information filtering, intelligent solution analysis, intelligent collaborative learning and class monitoring.

Our research is oriented towards the adaptive and intelligent Web-based educational systems. Adaptive systems are those systems that try to behave differently toward each student, based on the information accumulated in the student model, while intelligent systems apply artificial intelligence techniques in order to comply with the needs of their users.

### Adaptation Components

In what follows, we present the components of adaptation, to examine briefly adaptation levels and technology, adaptation models and ways of representing adaptation knowledge.

#### Adaptation Levels and Technologies

A method is defined as a notion of adaptation that can be presented at the conceptual level. A technique is a way to implement a specific method. Techniques operate on actual information contents and the presentation of hypertext links. It may be possible to implement the same method through different techniques and use the same technique for different methods (Stash, 2007).

According to the most recent classifications, there are two levels of adaptation:

- (1) Adaptation to the level of content and presentation adaptation;
- (2) Link level adaptation navigation or support adaptation.

Indeed, by abstracting hypermedia as a graph, we can either adapt its nodes (content level adaptation) or its edges (navigation level adaptation). Figure 1 provides a summary of the adaptive hypermedia technologies.

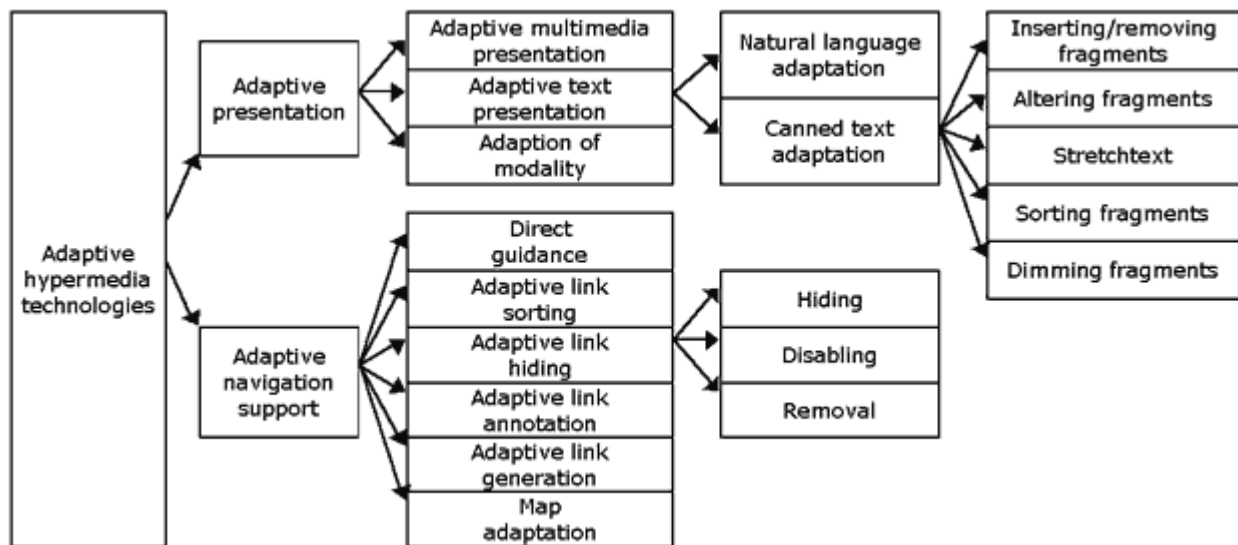


Figure 1. The updated taxonomy of adaptive hypermedia technologies (Brusilovsky, 2001).

While the distinctions of the taxonomy are important for identification and classification of adaptive systems, the implementation of these techniques can be achieved, using a small selection of fundamental data structures that can be combined to create powerful AH (adaptive hypermedia) systems.

#### Adaptation Models

The AHAM (adaptive hypermedia application model) provides a framework to express the functionality of adaptive hypermedia systems by dividing the storage layer into three parts that specify what should be adapted, according to what features it should be adapted, and how it should be adapted.

The Munich reference model preserves the three-layer structure of the Dexter model describing the network of nodes and links and the navigation mechanism. It extends the functionality of each layer to include the user modeling and adaptation aspects. The run-time layer, the storage layer and the within-component layer are represented as UML (Unified Modelling Language) subsystems as it is illustrated in Figure 2.

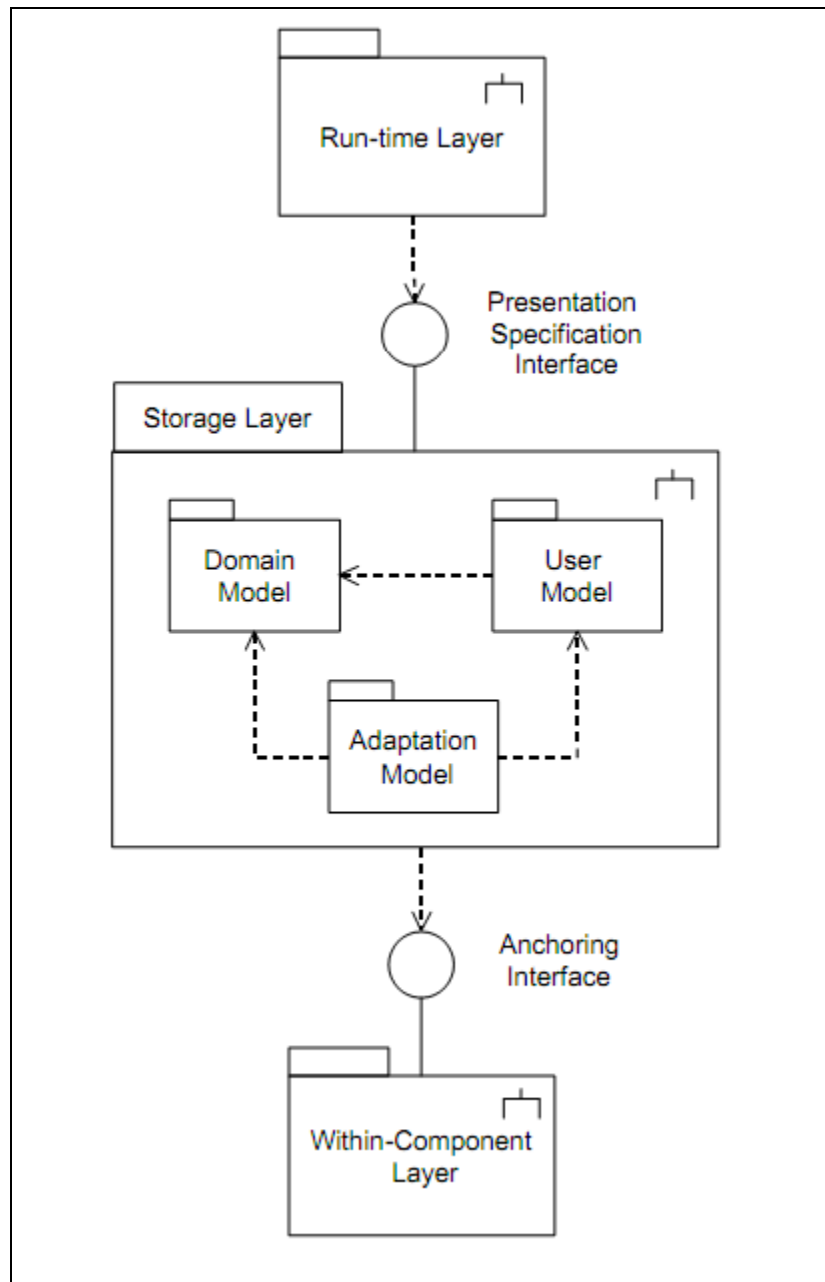


Figure 2. Architecture of adaptive hypermedia applications.

The run-time layer contains the description of the presentation of the nodes and links. It is responsible for users' interactions, acquisition of users' behaviors and management of the sessions.

The storage layer has more functionality than just storing information about the hypermedia structure. To support adaptation, the storage layer is divided into three sub-models:

(1) The domain meta-model that manages the basic network structure of the hypermedia system in terms of mechanisms, by which the links and nodes are related and navigated. The nodes are treated as general data containers;

(2) The user meta-model manages a set of users represented by their users' attributes with the objective to personalize the application;

(3) The adaptation meta-model consists of a set of rules that implement the adaptive functionality, i.e., personalization of the application.

The contents and structure within the hypermedia nodes are part of the within-component layer, which is not further detailed as its structure and contents depend on the application. The functionality of adaptive hypermedia systems is specified by three types of operations included in the classes of the reference model:

(1) Authoring operations are needed by adaptive hypermedia systems to update components, rules and user attributes, e.g., to create a link or a composite component, to create a rule, to add a user attribute to the model and to delete components or rules;

(2) Retrieval operations are required to access the hypermedia domain structure and the user model, e.g., to get a component, to get all rules triggered by a user's behavior or another rule;

(3) Adaptation operations are used to dynamically adapt the user model contents to users' behaviors and adapt the presentation to the current state of the user model, e.g., the adaptive resolver, the constructor or the rule executor.

The remainder of this paper presents the visual specification (slightly simplified) of the layers of the reference model and includes a few constraints of the formal specification out of a total of 70 constraints that comprise the complete specification of the Munich reference model (Koch, 2000).

### **Representation of Adaptation Knowledge**

We can identify several ways of addressing the issue of procedural knowledge, for more detail can be seen in studies of Kravcik and Gasevic (2007); in this case, we are interested in the use of ontologies. Because, from our point of view, different types of knowledge relevant to the adaptive learning could be represented using ontologies based on the use of RDF (resource description framework).

There are several authors that proposed the use of ontologies, such as Cristea (2004) (appropriate ontologies for each layer of the LAOS (Layered Algebraic Operators System) model, namely, domain, goal and constraint, user, adaptation and presentation ontologies) and Henze, Dolog, and Nejd (2004) (domain ontology, user ontology, observation (interaction) ontology and presentation ontology).

### **Integrating Adaptive Hypermedia Techniques**

In this section, we discuss the possibilities of using standardized metadata to describe and classify information stored in a RDF database to describe the knowledge, preferences and experiences of users accessing to that information. In addition, we will illustrate how to implement features of adjustment with the ultimate goal of implementing a personalized access to learning.

#### **Using RDF Metadata**

RDF is a graph model for formally describing Web resources and their metadata to enable automatic processing of such descriptions, developed by the W3C (World Wide Web Consortium) RDF.

A document structured in RDF is a set of triplets. An RDF triple is an association (subject, predicate

and object):

- (1) The subject is the resource to describe;
- (2) The predicate is a type of property applicable to this resource;
- (3) The subject is given one or another resource; the value of the property.

To annotate resources, we have identified a subset of best practices of 15 elements which are summarized in Table 1, using the categories defined in the LOM (learning object metadata) (Barker, 2005). It was found that these 15 attributes are enough to annotate and query our resources, and represent a compromise between sets of annotations more abstract and more detailed. Annotations of an entire course can be included in a single RDF file. All RDF triples are then imported into a relational database to customize the display of resources and ask others.

Table 1

*The 15 Attributes to Annotate and Query Our Resources*

|                |             |                                                                                                                                                |
|----------------|-------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| General        | Title       | dc:title                                                                                                                                       |
|                | Language    | dc:language                                                                                                                                    |
|                | Description | dc:description                                                                                                                                 |
| Lifecycle      | Contribute  | dc:creator with a lom:entity and the author in vCard format "name surname"<br>dcq:created with the date in W3C format                          |
| Rights         | Description | dc:rights                                                                                                                                      |
| Relation       |             | dcq:hasFormat<br>dcq:isFormatOf<br>dcq:hasPart<br>dcq:isPartOf<br>dcq:hasVersion<br>dcq:isVersionOf<br>dcq:requires<br>dcq:isRequiredBy        |
| Classification |             | dc:subject for content classification.<br>This attribute links to an entry in a hierarchical ontology, that is an instance of lom_cls:Taxonomy |

### Topic Ontologies for Content Classification

Personalized access means that resources are tailored according to some relevant aspects of the user, which are important or not depend on the personalization domain. For educational scenarios, it is important to take into account aspects like whether the user is student or a teacher, whether he/she wants to obtain a certain qualification, has specific preferences, and, of course, which his/her knowledge level for the topics covered in the course is.

Taking users' knowledge about topics covered in the current account is complicated, because it requires cognitive styles (Brown, Brailsford, Fisher, Moore, & Ashman, 2006). The general idea is that we annotate each document by the topics covered in this document. Topics can be covered by sets of documents, and we will assume that a user fully knows a topic if he/she understands all documents annotated with this topic.

To be more general, we use ontologies that are already part of classification systems and are internationally recognized.

ACM (Association for Computing Machinery) CCS (computer classification system) (Henze & Nejd, 1998)

2002), as a topic ontology for learning objects, has been used by the ACM since several decades ago, to classify scientific publications in the field of computer science. At the basic level, we found 11 nodes that split up in two more levels.

To classify a resource, the IEEE (Institute of Electrical and Electronics Engineers) learning object RDF binding guide (Nilsson, 2008) suggests the use of “dc:subject” with elements of a taxonomy that must be found in the Internet. Such a taxonomy hierarchy is an instance of “lom-cls:Taxonomy” and must be formatted in a RDF file where the topics and subtopics are separated using “lom\_cls:Taxon” and “lom\_cls:rootTaxon”. As discussed, we used ACM CCS whose the main structure is in Figure 3.

```
<dcq:SubjectScheme rdf:ID= ACM CCS >
<rdfs:label>ACM Computer Classification system</rdfs:label>
</dcq:SubjectScheme>
<lom cls:Taxonomy>
  <lom cls:rootTaxon>
    <ACM:ACM CCS rdf:about= http://www.Inte.org/prototype/ ACM CCS.rdf#D >
    <rdf:value>Software </rdf:value>
    <lom cls:taxon>
      <ACM:ACM CCS rdf:about= http://www.Inte.org/prototype/ACM CCS.rdf#D.1 >
      <rdf:value>PROGRAMMING TECHNIQUES</rdf:value>
      <lom cls:taxon>
        <ACM:ACM CCS rdf:about= http://www.Inte.org/prototype/ACM CCS.rdf#D.1.6 >
        <rdf:value>Logic Programming < /rdf:value>
        </lom cls:taxon>
      </lom cls:taxon>
    </lom cls:rootTaxon>
  </lom cls:Taxonomy>
```

Figure 3. Use of ACM CCS: Main structure.

## Describing Users

In recent years, there have been some efforts to standardize the information about a user, which should be maintained by a system. We choose the IMS LIP (Information Model Specification Learner Information Package) (2009).

IMS LIP is a structured information model. An XML (eXtensible Markup Language) binding is included, but is not meant to exclude other bindings. The information model contains both data and meta-data. The model defines fields, into which the data can be placed and the type of data may be put. Typical data might be the name of a learner, a course or training completed, a learning objective, a preference for a particular type of technology, and so on.

The learner information is separated into 11 main categories (as shown in Figure 4). These structures have been identified as the primary data structures that are required to support learner information. This composite approach means that only the required information needs to be packaged and stored.

An example of the accessibility category data is represented in Figure 5.

The “identification” category represents demographic and biographic data about the user. The “goal” category represents learning, career and other objectives of the learner. The QCL (qualifications, certifications and licenses) category is used for identification of qualifications, certifications and licenses from recognized authorities. The “activity” category can contain any learning related activity in any state of completion. The “interest”

category can be any information describing hobbies and recreational activities. The relationship category aims to relationships between core data elements. The “competency” category serves as slot for skills, experience and knowledge acquired. The “accessibility” category aims for general accessibility to learner information by means of language capabilities, disabilities, eligibility and learning preferences. The “transcript” category represents institutional-based summary of academic achievements. The “affiliation” category represents information records about membership of professional organizations. The “security key” is for set passwords and keys assigned to a learner.

### System Description

Our system is under development and we present here a primary prototype interface (see Figure 6).

Information will be presented in two different frameworks. The left frame displays the course structure based on metadata. The user can navigate through this structure and open documents in the right frame. Each resource is annotated according to the current user profile to express its relevance to the user. For annotations, we use a metaphor of wireless connection.

### Conclusions

In this article, we have studied the possibility of implementing traditional features of adaptive hypermedia in an open environment and discussed the standards for describing learning objects and architectural models based on the use of ontologies as a prerequisite for such an adaptation.

We discussed how this information can be expressed as RDF meta-data and how we can use queries over this meta-data. We also discussed the architecture of our hypermedia all based on the Munich reference model. We finally presented our system (adaptive hypermedia), which has been implemented as a prototype.

In our work, we will continue to improve links RDF. We will also experiment with compositions of resources and techniques of presentation and adaptation of different types of applications tailored functionality.

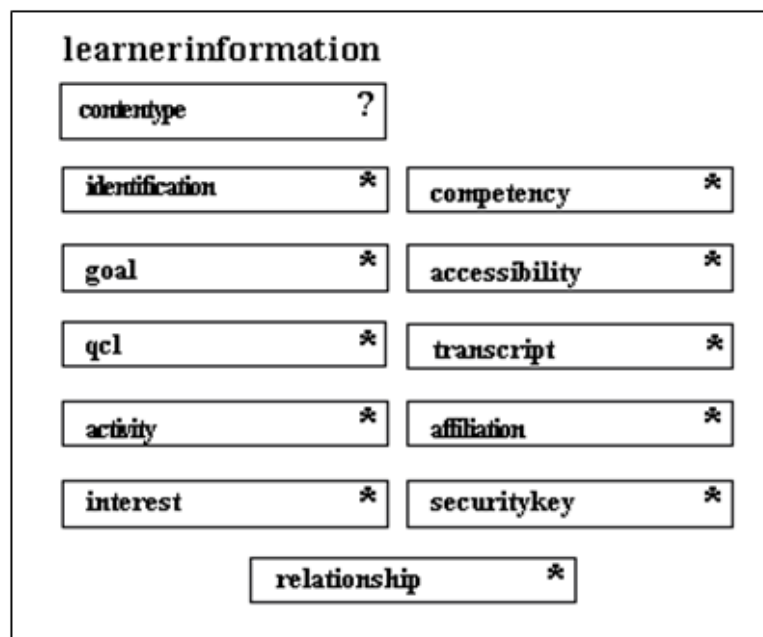


Figure 4. The IMS LIP core data structures.



```

<learnerinformation>
  <contenttype><referential>
    <sourcedid><source>
      IMS_LIP_V1p0_Example
    </source>
    <id>basic_1001</id>
    </sourcedid></referential>
  </contenttype>
  <accessibility>
    <contenttype><referential>
      <indexid>accessibility_01</indexid>
    </referential></contenttype>
    <language><typename>
      <tysource sourcetype="imsdefault"/>
      <tyvalue>French</tyvalue></typename>
      <contenttype><referential>
        <indexid>
          language_01
        </indexid>
      </referential></contenttype>
      <proficiency profmode="OralSpeak">
        Excellent
      </proficiency>
      <proficiency profmode="OralComp">
        Excellent
      </proficiency>
      <proficiency profmode="Read">
        Good
      </proficiency>
      <proficiency profmode="Write">
        Poor
      </proficiency>
    </language>
  </accessibility>
</learnerinformation>

```

Figure 5. An example of LIP accessibility information.

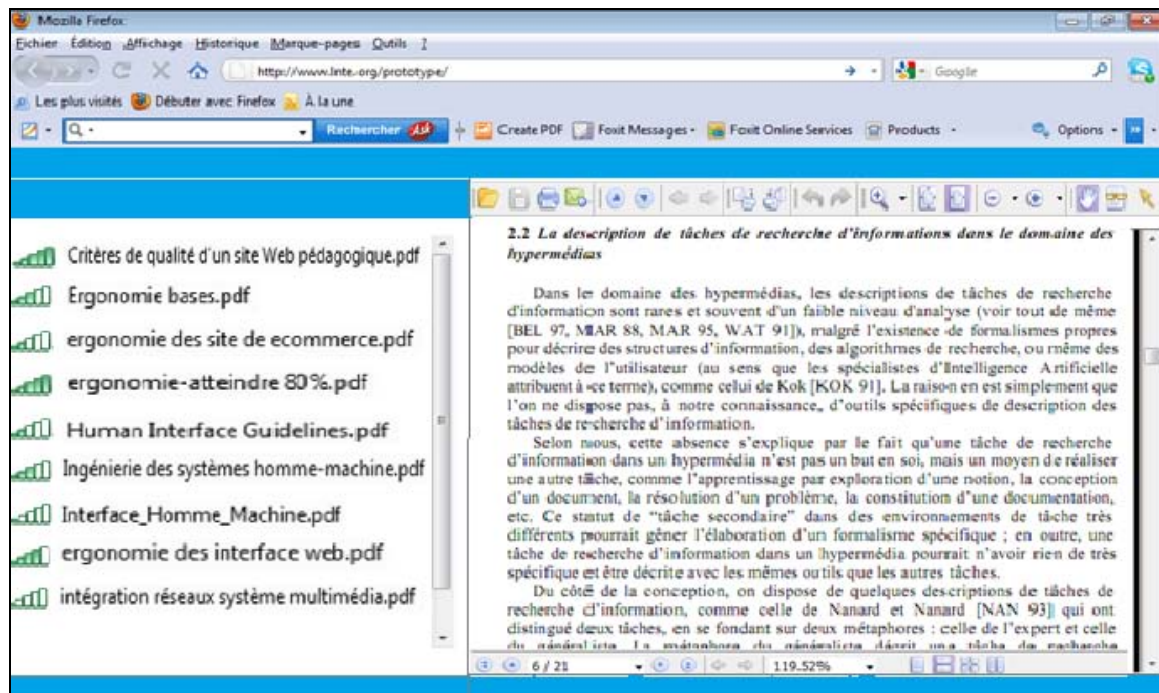


Figure 6. Prototype of the user interface.

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